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(71) Applicant: NORSK HYDRO A.S.
Bygdoy Allé 2
N-0257 Oslo 2(NO)

(72) Inventor: Oddvin, Reiso
Hoelsand Vn. 42
N-6600 Sunndalsora(NO)

(74) Representative: Allen, Oliver John Richard et al
Lloyd Wise, Tregear & Co. Norman House
105-109 Strand
London, WC2R 0AE(GB)

## (54) Improvements in and relating to the preparation of alloys for extrusion.

(57) A method for preparing an alloy for extrusion purposes, for example an aluminimum alloy comprising casting an ingot or billet, homogenizing the ingot or billet, cooling the homogenized ingot or billet, reheating the ingot or billet to a temperature above the solubility temperature of the precipitated phases in the matrix, holding the ingot or billet at the temperature above the solubility temperature and either quickly cooling the ingot or billet to the disired extrusion temperature to prevent precipitation of said phases in the alloy structure, or extruding the ingot or billet at the solubility temperature. This method improves the extrudability for the billet, in particular by making it possible to increase the extrusion speed.

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# IMPROVEMENTS IN AND RELATING TO THE PREPARATION OF ALLOYS FOR EXTRUSION

This invention relates to the preparation of an alloy for use in extrusion and in particular to the preparation of an aluminium alloy for use in extrusions.

In extrusion plants producing aluminium extrusions, aluminium is supplied to extrusion presses in the form of billets of suitable size which are heated to a suitable temperature. The extrusion presses generally consist of a cylinder/piston arrangement with the cylinder being provided at one end with a tool in the form of a die. The aluminium is forced through the die by means of the piston, to form an extrusion with the desired cross section or shape..

Due to their extrusion properties and the mechanical properties of the extrudate formed from them, AL-Mg-Si-alloys are often employed when extruding aluminium, more particularly alloys of the 6000 series for example, an alloy containing 0.35 1.5 weight % Mg 0.3 - 1.3 wight % Si. 0 - 0.24 weight % Fe, 0 - 0.10 weight % Mn 0.05 weight % Ti, the maximum amount of each of the impurities being 0.05 % and the total amount of each of the impurities being 0.15%.

The billets employed are produced by casting an aluminium alloy of the above-mentioned type. After casting the billets are homogenized by annealing at high temperature and thereafter cooled and reheated to a desired extrusion temperature.

It is generally required that:

- the surface of the extrusions should be of the best possible quality, that is, there should be no surface defects,
- the mechanical properties should be the best possible,
- the extrusion speed is as high as possible,
- the energy consumption is as low as possible during the extrusion process that is, the extrusion pressure is as low as possible.

Previously, attempts have been made to obtain optimum alloy compositions, and new methods for treating the above Al-alloys have been carried out to try to meet these requirements.

US Patent No. 3.222.227 describes a method of preparing a billet of an aluminium alloy of the 6063 type. The billet is homogenized and thereafter, cooled sufficiently fast to retain a sufficient amount of the magnesium and silicon in solid solution, preferably most of it, so that any precipitates created are present in the form ot small or very fine easily resolute $Mg_2Si$. Extrusions produced from such billets have, after ageing, improved strength and hardness properties. However, because of the rapid cooling, the billet is unnecessarily hard, which causes the extrusion speeds to be lower and the extrusion temperature has to be higher than is desirable. Moreover, preheating of the billet before extrusion has to be carried out most thoroughly and in a controlled way to avoid precipitation of a coarse beta-phase, $Mg_2Si$ at this point in time.

NO Patent Application No. 863864 discloses a billet made of an Al-Mg-Si-alloy and a method for producing such a billet, the object being to obtain control of the micro structure of the alloy by controlling the alloy composition and by controlling the casting conditions and more specifically the homogenization conditions. The billet, during the cooling process, is kept at a temperature from 250° C to 425° C for some time to precipitate nearly all the Magnesium as beta-phase $Mg_2Si$, and reduce to a minimum beta-phase $Mg_2Si$. Improved extrusion properties are said to be achieved.

The extrusion properties of an alloy are determined by the extrusion speed at which tearing begins on the surface of the extrusions, and the extrusion pressure necessary to begin the extrusion.

Tearing is initiated during the extrusion in those parts of the extrusions, or rather those phases of the alloy, when incipient melting occurs, as is discussed below. In the particular alloy discussed above the Mg-Si phases have the lowest melting point.

Although the object of NO Patent Application No. 863864 is to reduce the size of the Mg-Si-phases in the billet, these phases will, even if the particle size is smaller, be present and incipient melting with tearing will occur. The improved extrusion properties which are said to be achieved will therefore be only limited. Nor does any improvement either with regard to a reduction of extrusion work or of the mechanical properties of the extrudates, appear to be achieved.

The main object of the present invention is to provide a method for producing an alloy, for instance by casting an ingot or billet for extrusion purposes and which may consist of an Al-Mg-Si-alloy of the above-mentioned type, where the extrusion properties are essentially improved and where the mechanical properties of the extrudates in the terms of strength is substantially increased.

In accordance with the present invention a method of preparing an alloy for extrusion comprises casting an ingot of the alloy, homogenizing the ingot, cooling the homogenised ingot, reheating the ingot to a temperature above the solubility temperature of the precipitated phases in the matrix, holding the ingot at

that temperature until the phases are dissolved and either quickly cooling the ingot to the desired extrusion temperature to prevent new precipitation of the phases or extruding the ingot at that temperature.

Preferably the alloy is an aluminunium alloy.

The invention will now be further described by way of example with reference to the accompanying drawings in which:

Fig. 1 is a theoretical diagram showing the maximum extrusion speed as a function of billet temperature immediately before extrusion,

Fig. 2 is a cross-sectional view of the extrusion die used in the extrusion tests,

Fig. 3 is a diagram showing maximum extrusion speed plotted against billet temperature immediately before the extrusion is performed,

Fig. 4 is a diagram showing maximum extrusion pressure plotted against the billet temperature, and

Fig. 5 is a diagram showing ultimate tensile strength plotted against the billet temperature.

The present invention is based on the theory that incipient melting first occurs in the coarse Mg-Si-phases of the metallic structure which have the lowest melting point, and that the tearing of the extrusion surface occurs at these sites when the temperature in the metal reaches the melting temperature for these phases.

If the coarse Mg-Si-phases are avoided, incipient melting is prevented, which again will allow the extrusion speed to be increased. The Mg-Si-phases are soluble in all the 6000-alloys and will no longer be present if the metal is held at a temperature above the solubility temperature.

Referring to the "extrusion limit diagram" shown in Fig.1, the above theory means that if the billet is heated to a sufficiently high temperature for long enough to dissolve the Mg-Si-phases before extrusion, there will be a new peak in the diagram, indicated by reference numeral 1 in the diagram.

The curve on the left hand side, 2, shows the maximum press speed with the available extrusion pressure. The curve on the right hand side, 3, shows the maximum values above which tearing occurs in the metal due to incipient melting, while the curve on the far right, 4, shows the maximum values above which tearing occurs in the Al-matrix itself.

The extra peak in the diagram is expected to occur only in alloys where incipient melting occurs.

If the billets, as mentioned above, are firstly heated to a temperature above the solubility temperature for Mg and Si for a sufficient time so that the Mg-Si-phases are dissolved and thereafter are cooled to a desired extrusion temperature quickly enough to prevent precipitation of new, coarse Mg-Si-phases, it is possible to achieve a further increase in extrusion speed at the lower billet temperature. These billets will have an increased extrusion speed compared to billets which are heated conventionally to the same temperature, compare the dashed line, 6, in Fig. 1.

The following example is intended to illustrate in a non-limiting manner the advantages of the invention.

Example

Extrusion tests were performed to compare the extrusion properties of billets produced according to the invention against the extrusion properties of billets made of the same alloy, but produced in a conventional way.

Billets in the form of rods of diameter 228 mm were produced by casting an alloy, AA6063, and then cut into sections 711 mm in length. The alloy composition is shown in the table below.

| Alloy | Mg | Si | Fe |
|---|---|---|---|
| AA 6063 | .60 | .48 | .17 |

The billets were homogenised according to standard practice, ie 6 hours at 582° C, and thereafter cooled at a minimum cooling rate of 194° C/h between 510° C and 204° C.

After the homogenization the billets were provided with sample numbers and heated according to a desired "temperature program".

The heating period for the billets was approximately 35 minutes. The samples which were cooled prior to extrusion, were cooled to a desired temperature without using any kind of forced cooling. The cooling period was up to 20 minutes for the lowest cooling temperature.

After the above heating program was performed, the billets were extruded through a special die shown in Fig. 2. The extrusion die is provided with recesses, 5, which in the extrusions result in small ribs. The expression "extrudability" as used herein refers to the maximum extrusion speed, V maks, which is

achieved before tearing occurs in the ribs. With the present extrusion tests five different billets were used for each billet temperature, ie the temperature of each of the billets immediately before the extrusion was performed.

Maximum extrusion speed before tearing occured is plotted vs. billet temperature in Fig. 3. "X" represents billets which were heated directly to the desired extrusion temperature after homogenization in the conventional way, while "O" represents billets heated to a temperature above the solubility temperature and then cooled to the desired extrusion temperature. As indicated by the dotted line in Fig. 3, a significant increase (app. 60%) in extrusion speed is achieved by producing the billets according to the method.

From the phase diagram for the alloy (60603) used in the tests, the solubility temperature was estimated to be about 483° C, which corresponds to the changes in maximum extrusion speed, the break-through pressure for the billets and the surface temperature for the directly heated billets. As the coarse Mg-Si-phases are dissolved, the extrusion speed will increase due to the changes in the mechanisms which initiate the tearing of the material. When these phases are present in the metal structure the tearing is expected to occur due to incipient melting. This occurs, as previously mentioned, due to the fact that the material contains small agglomerates of phases which have lower melting points than the rest of the material. These agglomerates may for instance consist of $Mg_2Si$ + Si + Al (liquid at 555° C), or AlFe (Mn)Si + $Mg_2Si$ + Si + Al (liquid at 548° C). When these temperatures are exceeded during the extrusion of the metal, incipient melting will occur and cause surface defects such as tearing.

In Fig. 4 the break-through pressure for he extrusion (the maximum pressure before extrusion commences) is plotted against the billet temperature. The curve passing through the points "O" defines the maximum, average pressure for billets extruded according to the invention, while the slightly less inclining curve passing through the points "X" defines the average, maximum pressure which was measured for the billets extruded the conventional way, i.e. billets directly heated to the desired extrusion temperature.

As can be seen from this figure, a slight increase in extrusion pressure is registered for the billets produced according to the present invention. This probably has to do with the larger amounts of Mg and Si dissolved in solid solution in the metal than is the case with the billets produced conventionally. The small increase in extrusion pressure is, however, unimportant compared to the increase in extrusion speed for the billets produced according to the present invention.

With regard to surface quality, the amount of "pick-up" (surface defect), was determined by visual inspection of each extrusion sample. Each sample was graded with regard to surface quality, Grade I indicating the finest surface and Grade III the roughest surface. The samples were graded as follows:

| Sample No. | Billet temperature | Grading |
|---|---|---|
| 1 | 442 | I-II |
| 2 | 432 | I-II |
| 3 | 446 | II |
| 4 | 477 | II |
| 5 | 488 | II |
| 6 | 506 | I |
| 7 | 511 | I |
| 8 | 527 | I |
| 9$^x$ | 466 | I |
| 10$^x$ | 466 | I |
| 11$^x$ | 430 | I |

$^x$ = Cooled down from 538° C.

As can be seen from the table on page 11, the surface quality is significantly improved by increasing extrusion temperature.

Furthermore, the samples extruded from billets produced according to the present invention have essentially better quality (less "pick-ups") than the samples extruded from billets produced according to the conventional method.

Testing of mechanical properties.

After the extrusion was performed, the extrusions were water- quenched at the press (standing wave) and samples were aged at 185° C for five hours.

Two parallel samples of the aged extrusions were provided for tensile stress tests. The examples were taken from the middle, flat part of the extrusions. The results from the tests are set out in the table below.

| Sample No. | Billet temp. | Rpo 2 N/mm² | Rm N/mm² | Elongation % |
|---|---|---|---|---|
| 1ˣ | 442 | 221 | 241 | 13.5 |
| 2ˣ | 432 | 213 | 234 | 12.9 |
| 3ˣ | 446 | 245 | 263 | 10.7/13.2 |
| 4ˣ | 477 | 258 | 274 | 13.7 |
| 5ˣ | 488 | 258 | 274 | 8.6/14.0 |
| 6ˣ | 506 | 260 | 275 | 12.5 |
| 7ˣ | 511 | 262 | 276 | 12.7 |
| 8ˣ | 527 | 263 | 276 | 13.4 |
| 9○ | 466 | 252 | 266 | 13.5 |
| 10○ | 466 | 259 | 271 | 12.8 |
| 11○ | 430 | 256 | 269 | 11.9 |

○ = Billets cooled down from 538° C.

ˣ = Billets produced according to the conventional method.

In Fig. 5 the values of tensile strength set out in the table are plotted against the billet temperature.

As can be seen from Fig. 5, the strength of the material increases as the billet temperature immediately before extrusion is increased. Further it can be seen that the extrusions which were extruded from billets produced according to the present invention have improved strength compared to the extrusions produced according to the conventional method, especially when the billet temperature is low.

The above examples therefore illustrate that billets extruded according to the present invention have improved properties with regard to extrusion speed, surface quality and strength, compared to billets extruded according to the conventional method.

As well as the tests carried out with the alloy AA 6063 discussed above, corresponding tests with another alloy, AA 6351 were performed. The results from the tests with this alloy showed the same improvements regarding extrusion speed surface quality and strength as with alloy AA 6063.

Although discussed with reference to the Al-Mg-Si-alloys of the 6000-series, the method may be employed with all Al-alloys where incipient melting occurs due to precipitated phases which are soluble at higher temperatures. Further, it is expected that the method may also be used with equal success with other alloys for example the copper alloys.

## Claims

1 A method of preparing an alloy for extrusion comprising casting an ingot of the alloy, homogenizing the ingot, cooling the homogenised ingot, reheating the ingot to a temperature above the solubility temperature of the precipitated phases in the matrix, holding the ingot at that temperature until the phases are dissolved and either quickly cooling the ingot to the desired extrusion temperature to prevent new precipitation of the phases or extruding the ingot at that temperature.

2. A method as claimed in Claim 1 wherein the alloy is an aluminium alloy.

3. A method as claimed in Claim 1 wherein the alloy is a copper alloy.

4. A method as claimed in Claim 2 wherein the alloy is a structural hardening Al-Mg-Si-alloy with 0.35 - 1.5 weight % Mg, 0.35 - 1.3 weight % Si, 0 -0.24 weight % Fe, 0 - 0.20 weight % Mn, 0-0.05 weight % Ti, the maximum amount of each of the impurities being 0.05% and them maximum total amount of impurities being 0.15%, the precipitated phases being the Mg-Si phases.

5. A method as claimed in any preceding claim wherein the ingot is cast by a short forming or hot top direct chill process.

FIG. 1

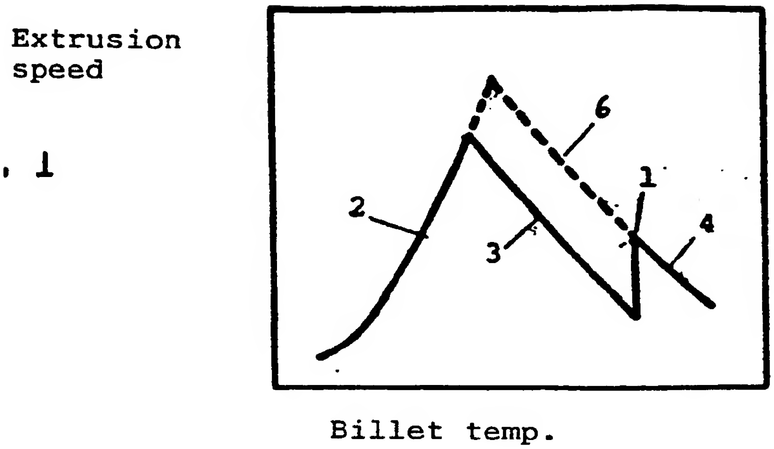



FIG. 2

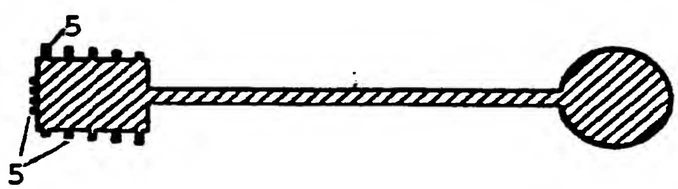
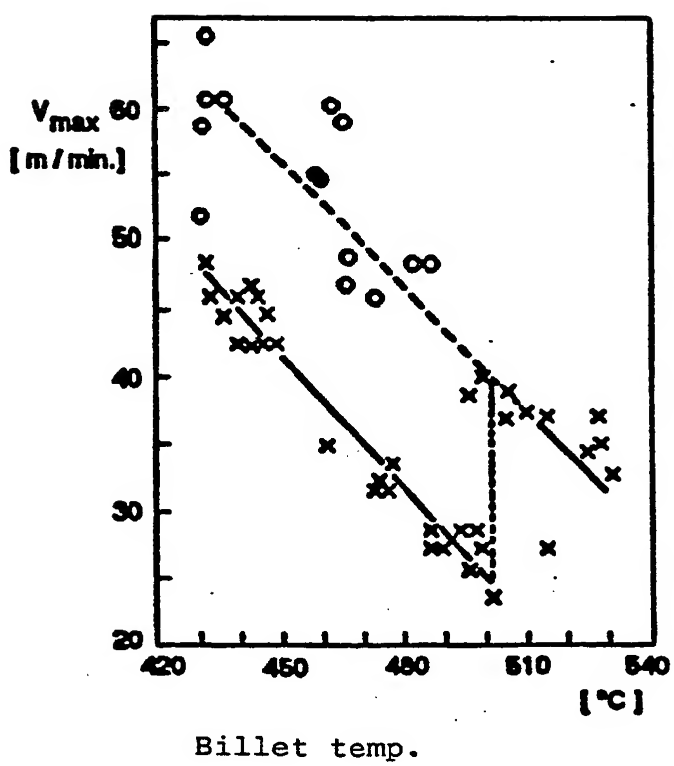



FIG. 3



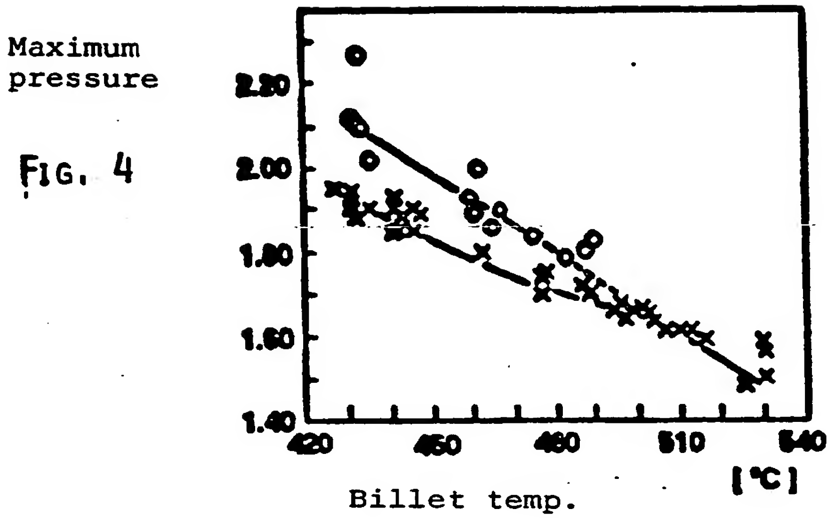

Maximum pressure
2.20
2.00
1.80
1.60
1.40
420
450
480
510
540
[°C]
Billet temp.

FIG. 4

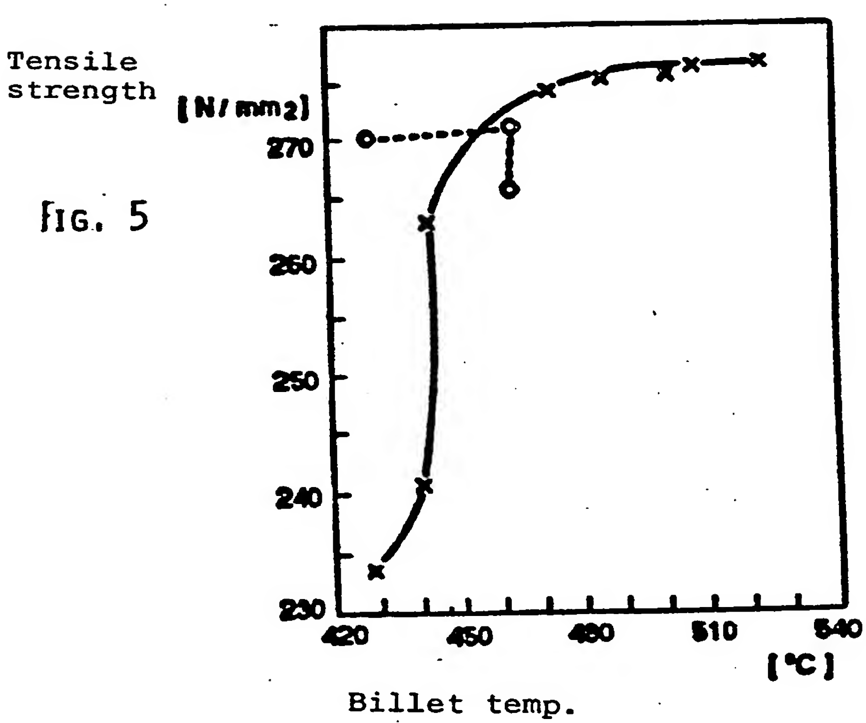

Tensile strength
[N/mm2]
270
260
250
240
230
420
450
480
510
540
[°C]
Billet temp.

FIG. 5

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number

EP 88 30 6629

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.4) |
|---|---|---|---|
| X<br>Y | GB-A-1 122 198 (OLIN MATHIESON CHEMICAL CORP.)<br>* Claims 1-3; page 2, lines 61-118 *<br>--- | 1,2,4<br>3,5 | C 22 F 1/05<br>C 22 F 1/08<br>C 22 C 21/08 |
| Y | EP-A-0 222 479 (ALCAN INTERNATIONAL LTD)<br>* Claims 1,2,7,8 *<br>--- | 5 | |
| Y | JOURNAL OF MATERIALS SCIENCE LETTERS, vol. 5, no. 4, April 1986, pages 445-449, Chapman and Hall Ltd, London, GB; P.K.SENGUPTA et al.: "Microstructural refinement of a copper-base age-hardenable alloy through thermomechanical processing"<br>* Page 445, left-hand column, last paragraph *<br>--- | 3 | |
| A | GB-A-1 052 887 (VEREINIGTE DEUTSCHE METALLWERKE AG)<br>* Claims 1,2 *<br>--- | 1,2,4 | TECHNICAL FIELDS SEARCHED (Int. Cl.4) |
| A | GB-A- 917 385 (KAISER ALUMINIUM AND CHEMICAL CORP.)<br>* Claims 1-5 *<br>--- | 1,2,4 | C 22 F<br>C 22 C |
| D,A | US-A-3 222 227 (E.R.BRAUGH et al.)<br>* Example 1 *<br>----- | 1,2,4 | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 17-10-1988 | GREGG N.R. |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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